

A 269392

**BASEWIDE
ENGINEERING EVALUATION-
COST ANALYSIS
FOR SOIL VAPOR EXTRACTION**

SITE SPECIFIC DOCUMENT OU D / Site S

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Section 1 INTRODUCTION

This document supports the use of soil vapor extraction (SVE) as the non-time-critical removal action for areas having high levels of volatile organic compound (VOC) contamination in Site S, which is located in Operable Unit (OU) D. This SVE removal action is part of the initial basewide SVE removal action at McClellan Air Force Base (McAFB). The principal objective of basewide SVE removal actions is to achieve early risk reduction by removing a significant quantity of VOCs from soils in the vadose zone, intercepting an exposure pathway, or preventing additional flux to groundwater.

This document is a companion to the Basewide Engineering Evaluation-Cost Analysis (EE/CA) General Evaluation Document. The General Evaluation Document provides the long-term plan to standardize and streamline the use of SVE removal actions at McAFB by establishing SVE as the presumptive remedy for McAFB for removal of VOCs from the vadose zone, outlining a site selection methodology for SVE removal actions, and providing a baseline SVE configuration and cost estimate.

Site S is currently the subject of a Treatability Investigation for SVE systems for application at McAFB. The Site S SVE system has been installed, and was brought into successful operation in March 1993. The Site S SVE system is composed of 17 extraction wells drawing from three horizons in the vadose zone, extraction pumps, catalytic oxidizing system, and associated equipment. After eight weeks of operation, the system removed 46,000 pounds of chlorinated VOCs, but was shut down because of nuisance emissions of acid gases resulting from the oxidation of the chlorinated hydrocarbons withdrawn at the site. An acid gas control system is currently being installed, and startup is expected in fall 1993. In addition, steps are being taken to reduce noise generated by the SVE system.

During the eight-week period of operation, the SVE system demonstrated high removal rates for chlorinated hydrocarbons while enhancing the biodegradation of non-chlorinated hydrocarbons, thus verifying that the process is suitable for the site.

This document summarizes the information that was used to evaluate the suitability of Site S for SVE and the initial results of the operation. Using these data, it is concluded that SVE will remove substantial quantities of contaminants at this site. It is recommended that SVE be continued at Site S as a removal action, and that it be accompanied by data collection and analysis to allow continued evaluation of SVE and its application to McAFB.

Section 2

SITE CHARACTERIZATION

Site S covers an area of approximately 9,000 square feet (0.23 acres) in OU D. Site S is 1 of 12 waste disposal sites in OU D, and has been identified as a former fuel and solvent disposal pit. Figure 2-1 shows the location of Site S within OU D. Figure 2-2 shows increased detail in the Site S area, including locations of wells and boreholes (other than SVE extraction wells) in the area. The waste in Site S is overlain by approximately 10 feet of soil, and extends to a depth of about 28 feet below ground surface. The water table in this area is about 100 feet below ground surface.

In 1985, an impermeable cap covering about eight acres, constructed from plastic sheet and about 2-3 feet of soil, was installed to cover the entire area of OU D. The cap was put in place to limit infiltration of rainwater and to reduce migration of contaminants to the groundwater. The cap covers the entire area shown in figure 2-2.

Investigation Results: Soil and Groundwater Sampling

Soil borings were taken in OU D in 1985. As shown in figure 2-2, the Site S area was sampled by shallow pit boring BP-21 and deep pit boring BP-20. BP-20 was located adjacent to the present SVE extraction well system. Figure 2-3 shows a portion of the soil contamination concentration data from these borings. The data are consistent with the historical evidence that the site had been used primarily as a disposal point for waste fuels and solvents and that it had not been used extensively for the disposal of burn materials or industrial solids. The borings detected pollutant soil concentrations of a variety of VOCs (including chlorinated hydrocarbons and petroleum hydrocarbons) ranging from 1,000-30,000 micrograms per kilogram, while showing low levels of organic carbon and metals.

The 1985 soil borings provided the initial basis for the selection of Site S for the Treatability Investigation. As a part of the site characterization work for the investigation, additional wells were drilled in the locations shown in figure 2-4 and soil samples were taken for analysis. These borings were converted to extraction wells for the SVE system. The wells are shown in cross section in figure 2-5, which also shows the measurements of total VOCs in micrograms per kilogram of soil. The spatial pattern of contaminants shown in figure 2-5 is typical of the results of other analyses with contamination concentrated in the region between 10 and 30 feet deep. There were some indications of increased contamination at greater depths in the northward direction, and occasional high readings just above the groundwater.

Using the soil contamination concentration data from GC-MS 8240 analysis, the mass of the VOC contaminants is estimated to be 5,800 pounds. This includes both chlorinated and non-chlorinated compounds. Measurements using the GC

Section 2

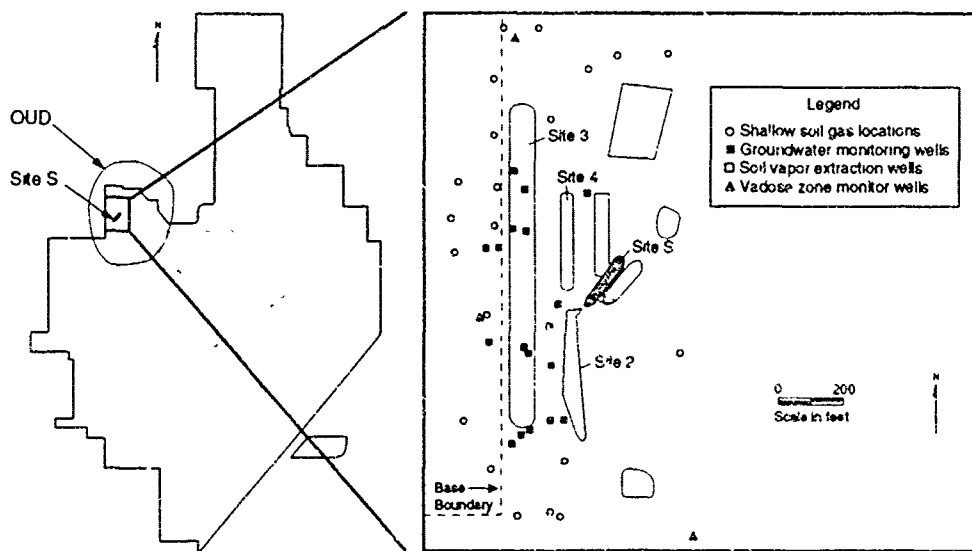
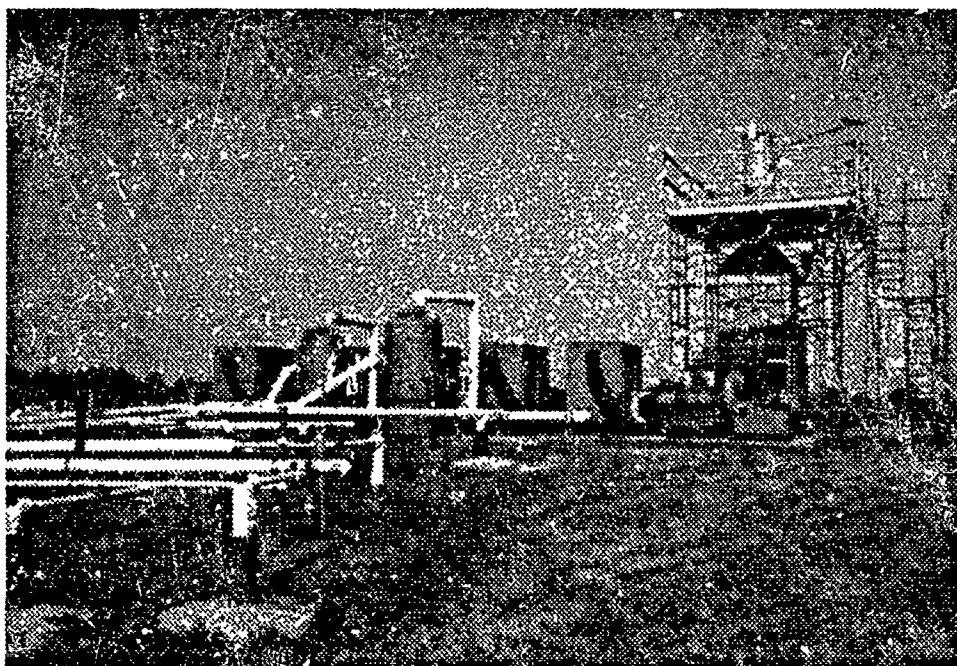
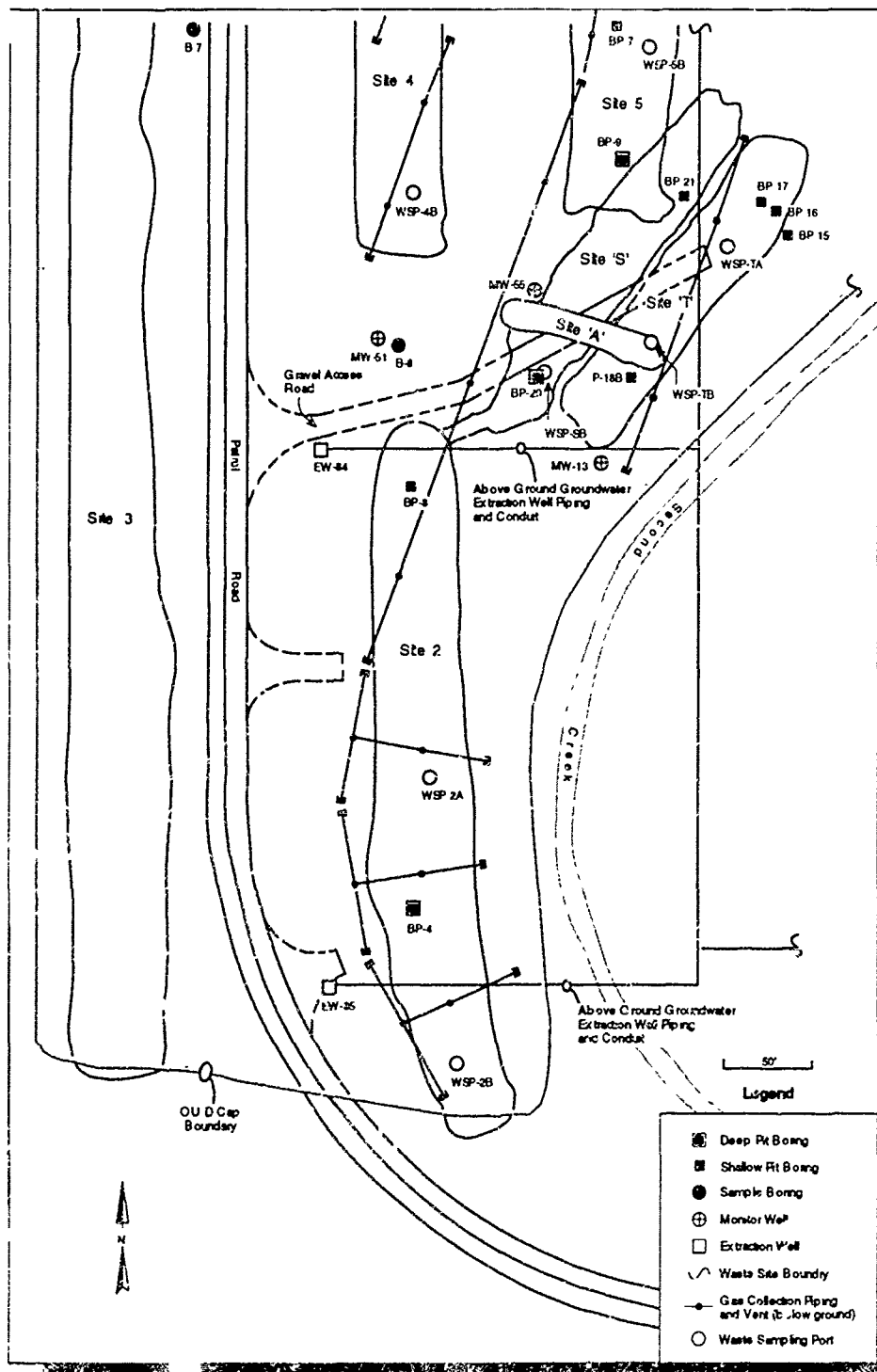


Figure 2-1
Site S Location
Maps and
Photo

Section 2



Section 2

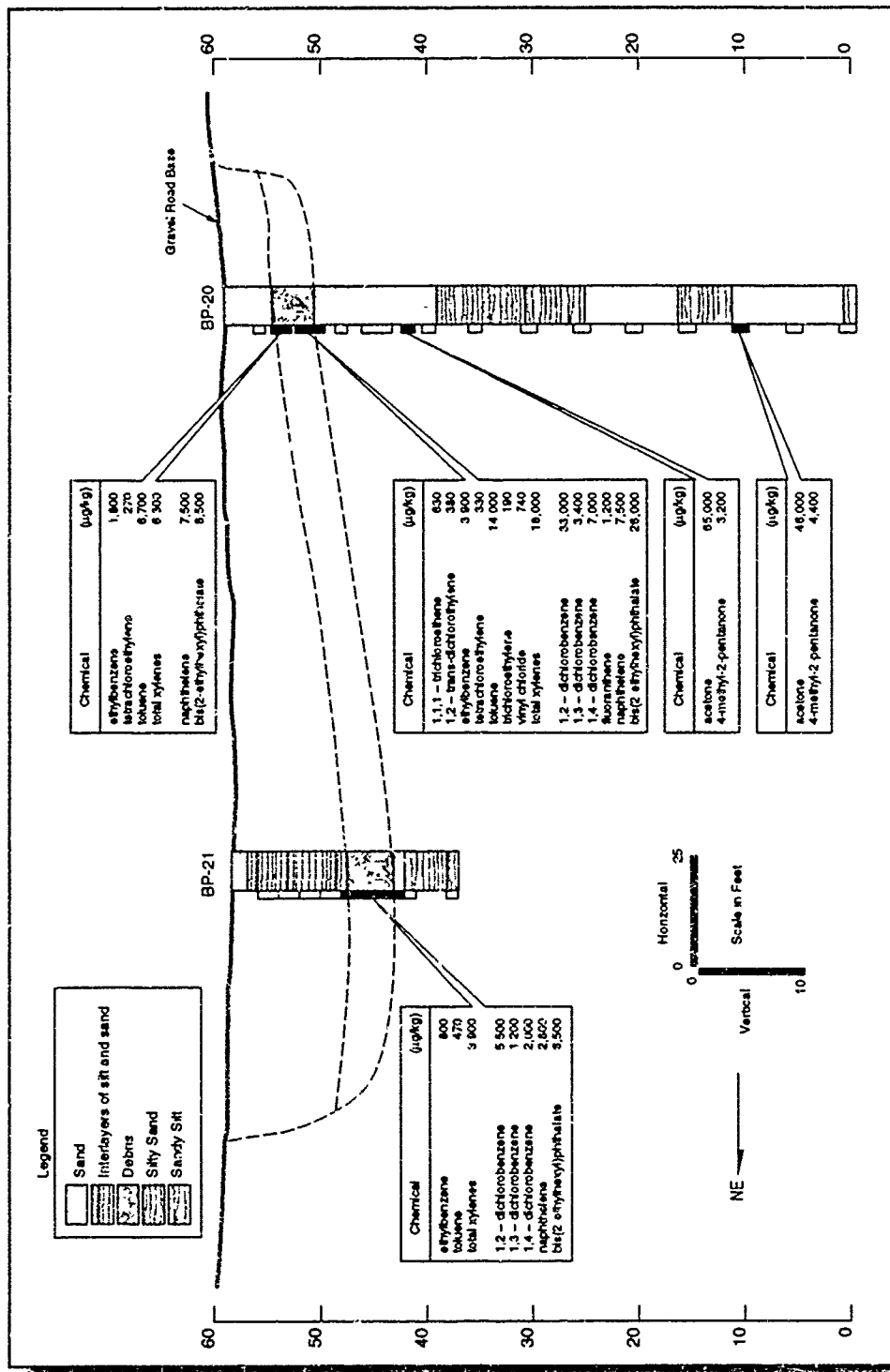
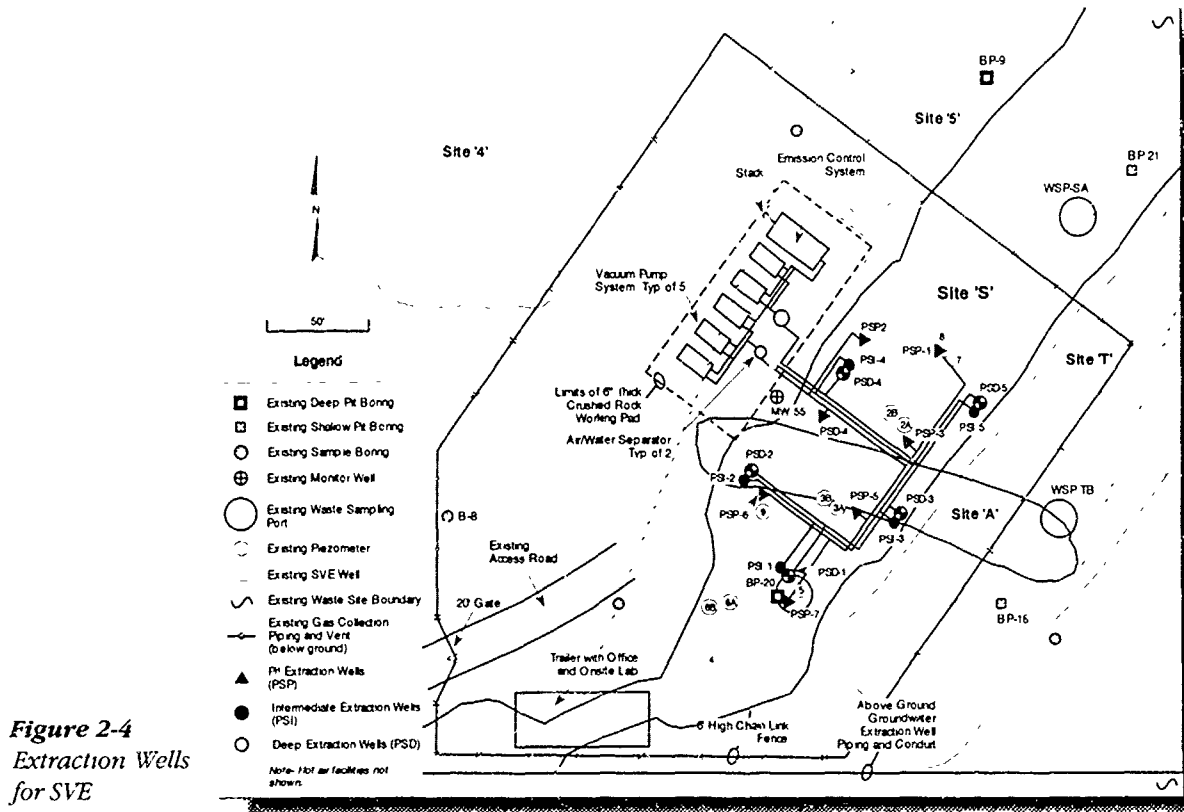


Figure 2-3
 Site S
 Boreholes -
 Geologic Data
 and Soil
 Contamination
 Data

Section 2



Section 2

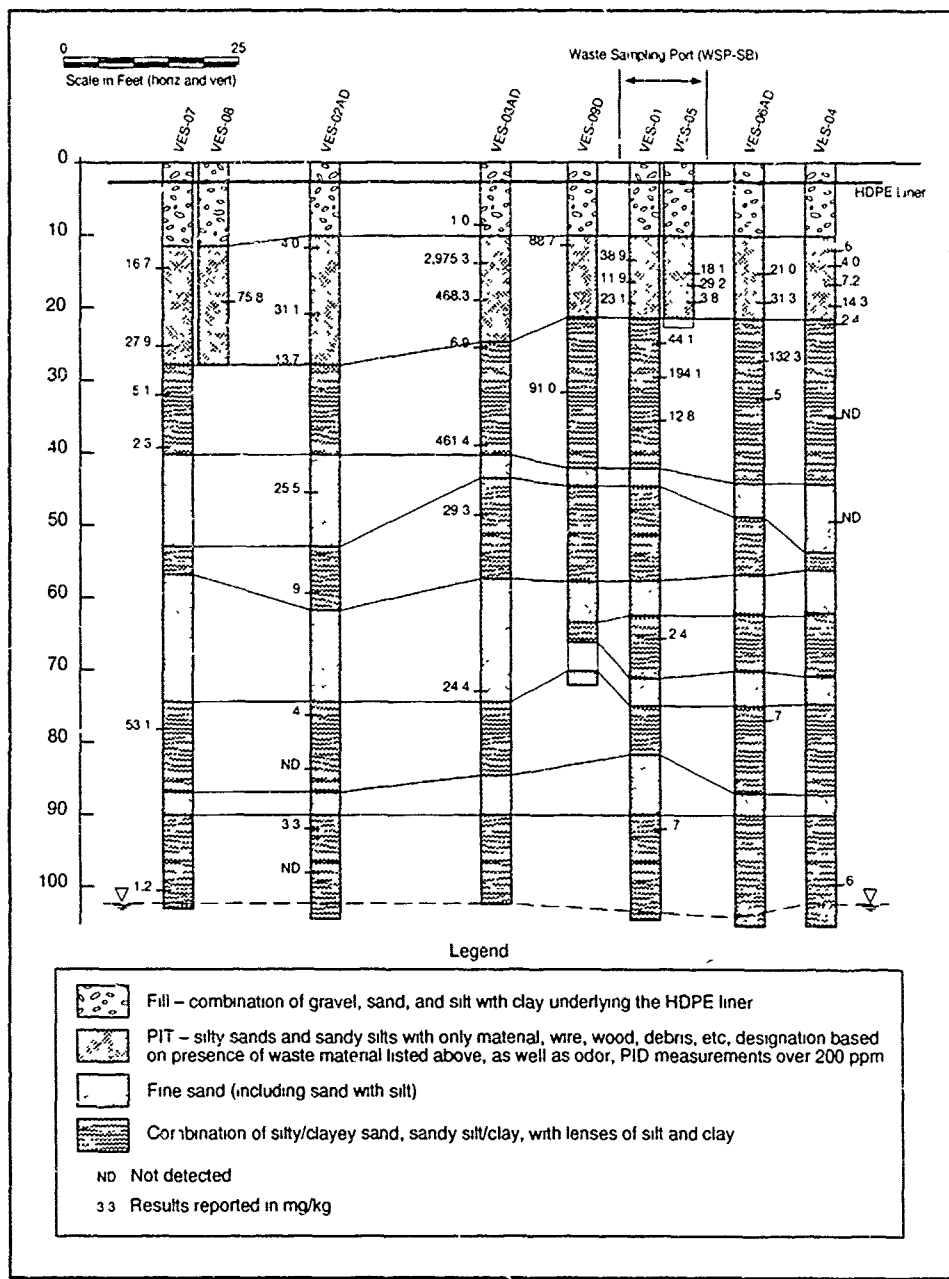


Figure 2-5
 Site S Extraction
 Wells - Geologic
 Cross Section of
 Total VOC by a
 Specific Method

Section 2

8010 analysis to distinguish among the chlorinated VOCs showed a poor correlation with the 8240 data, so the relative contributions of different species to the mass calculation could not be estimated. SVE operation at Site S appears to show that the actual mass of pollutants is substantially higher than estimated. However, since the area from which the pollutants are withdrawn is not accurately known, a direct comparison cannot be made.

The vadose zone contamination near Site S and other areas in OU D is a likely source of groundwater contamination, as documented by many monitor wells in both the A and B zones. In the A zone, the highest contaminant concentrations are reported from wells located within or near the cap. Compounds detected at maximum concentrations exceeding 100 µg/L at least once since 1986 are BZ, DCA11, DCA12, DCBZ12, DCE11, DCE12, MTLNCL, MVC, PCE, TCA111, and TCE (see glossary for chemical compounds). In the B zone, fewer of these analytes have been detected, and they have generally been at much lower maximum concentrations. Only DCE11, MTLNCL, and TCE have exceeded 100 µg/L at least once, and most other analytes have not been reported above 20 µg/L. In general, concentrations in the groundwater have been decreasing since 1986, after the installation of the cap and groundwater treatment started.

Investigation Results: SVE Operation

During operation of the SVE system, daily, weekly, and monthly gas samples were planned to be taken from the extraction wells and piezometers and at various points within the gas handling system. The resulting data, expressed as concentrations or as mass flow rates, allow calculation of the rate and cumulative amount of pollutants removed. The time trend provides insight into the mechanisms occurring for removal of pollutants.

Hydrocarbon Degradation

Figures 2-6 and 2-7 show the time trend of oxygen and carbon dioxide concentrations in the withdrawn gases for the first four weeks of operation. Before pumping began, the extraction wells indicated that the underground site was anoxic. After pumping began, oxygen increased in one day to about 10 percent and showed a slow rise thereafter. During the four weeks of operation shown here, oxygen concentrations had not increased to the 20 percent content of ambient air, indicating that biological activity was consuming oxygen in the subsurface, and that the impermeable cap is at least reasonably tight.

Carbon dioxide showed a high initial level of about 17 percent, decreasing to about 6 percent toward the end of the initial eight weeks of operation. Anoxic conditions prior to operation, and the continuing presence of carbon dioxide during SVE operation, indicate that biodegradation of the soil gases was and is a continuing process. With appropriate assumptions concerning the type of hydrocarbon

Section 2

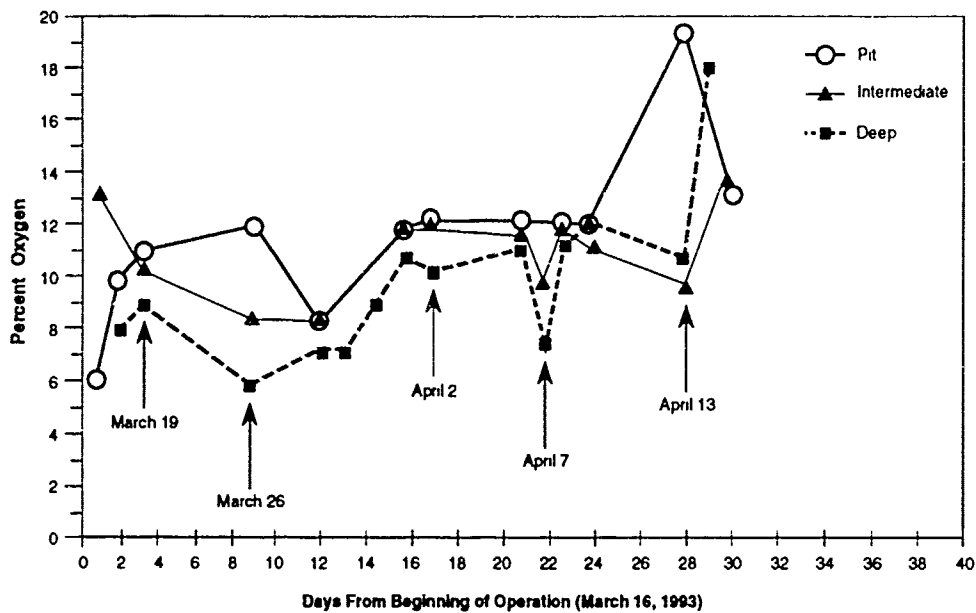


Figure 2-6
SVE Manifold -
Oxygen
Concentrations

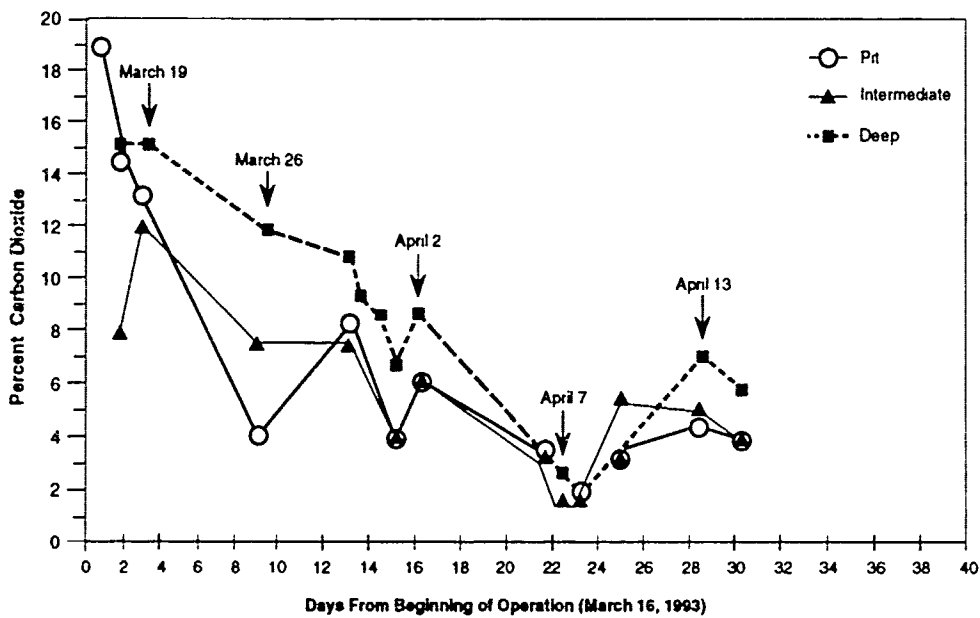


Figure 2-7
SVE Manifold -
Carbon Dioxide
Concentrations

Section 2

materials present (e.g., hexane equivalent), one can compute a mass balance that relates the mass of hydrocarbon biodegraded to the resulting mass of carbon dioxide withdrawn by the SVE system.

The initial high carbon dioxide concentration may result from withdrawal of carbon dioxide stored in soil pore spaces that were generated from long-term hydrocarbon degradation preceding SVE operation. The mass of carbon in the initial decrease of carbon dioxide concentration corresponds to a degraded quantity of hydrocarbons of about 35 tons.

The relatively constant carbon dioxide concentration observed in the final two weeks shown in figure 2-7 is assumed to be the result of ongoing degradation that will presumably continue for some period into the future. Based on a carbon dioxide concentration of about 6 percent and the design flow rates, a carbon dioxide mass of about 480,000 pounds was withdrawn over four weeks, implying a mass of hydrocarbon (hexane equivalent) of approximately 150,000 pounds (75 tons) that was degraded during this period. To place the amount of 75 tons in perspective, the mass of soil in an area 50 feet square and 40 feet deep is about 8,000 tons.

The estimated degradation masses cannot be considered an accurate calculation of the amount of hydrocarbons degraded during this period. The calculation is derived from limited data and is based on a hexane equivalent, not the actual (unknown) mix of hydrocarbons. In addition, the calculation does not include the carbon mass incorporated into the biomass responsible for the degradation. The calculation implicitly assumes that the degradation reactions are the only source of carbon dioxide, as no background oxygen and carbon dioxide data are available.

Even with these caveats, it appears that there is a very substantial amount of biodegradation taking place and that there has been and is a large quantity of material present. However, no data are available to establish the depth and real extent of contamination. Non-chlorinated hydrocarbons indicators of petroleum products such as benzene are present only in very low concentrations in the SVE gases.

During the initial testing of the SVE system, air permeability measurements indicated a radius of influence of about 30–60 feet around each well. The radius of influence measures the distance between a pair of wells for the distance through which air enters the extraction wells. For Site S, the path of air movement will be influenced by the presence of the cap covering OU D, and by the differences in soil permeability for air traveling horizontally versus vertically. Therefore, to the degree that the cap is actually impermeable, the gas removed at Site S has already flowed through much of the OU D cap area before reaching the SVE system.

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Because the cap confines the gas flow, the flow velocity decreases only with the reciprocal of the distance from the extraction wells, rather than with the square of the reciprocal for unconfined flow. For example, at 2,500 cfm of soil vapor withdrawn, the underground air velocity is about 0.4 feet/minute at a 40-foot radius from the center of the extraction system, and is still nearly 0.1 feet/minute at a 160-foot radius (assuming cap impermeability and homogeneous soils). Since it is likely that there are other contaminant sources elsewhere than Site S under the impermeable cap, some fraction of the pollutants withdrawn by the existing SVE well system may be from areas of OU D outside Site S.

Currently, there are no provisions for soil gas measurements in the area surrounding the SVE system. Thus, although it appears that substantial contaminants are present in the immediate vicinity of the SVE extraction wells, neither the lateral or depth extent of the contamination are defined by the data available. Additional observation and extraction wells will be installed in the area surrounding Site S so that the extent of the contamination may be characterized. These wells can also be used as additional extraction points.

VOC Removal

Figure 2-8 shows the concentration of trichloroethane (TCA) in the shallow extraction wells in the SVE system as a function of time for the first four weeks of operation. The withdrawn gas shows a pollutant concentration of several thousand parts per million (volume). A concentration in this range may indicate the presence of free product in the area through which the air is drawn. By the end of the four weeks of operation shown here, there was no indication that the concentration had reached a peak or was declining. Since there are no surrounding monitor wells, it is not possible to identify the actual extent or source of the pollution. A similar trend is indicated in figure 2-9, which shows the actual mass flow of the total speciated VOCs withdrawn by the shallow wells.

Calculations show that about 46,000 pounds of chlorinated hydrocarbon material were withdrawn and oxidized by the SVE system during the eight weeks of initial SVE operation.

Section 2

Figure 2-8
SVE Pit Manifold -
1, 1, 1-TCA
Concentrations

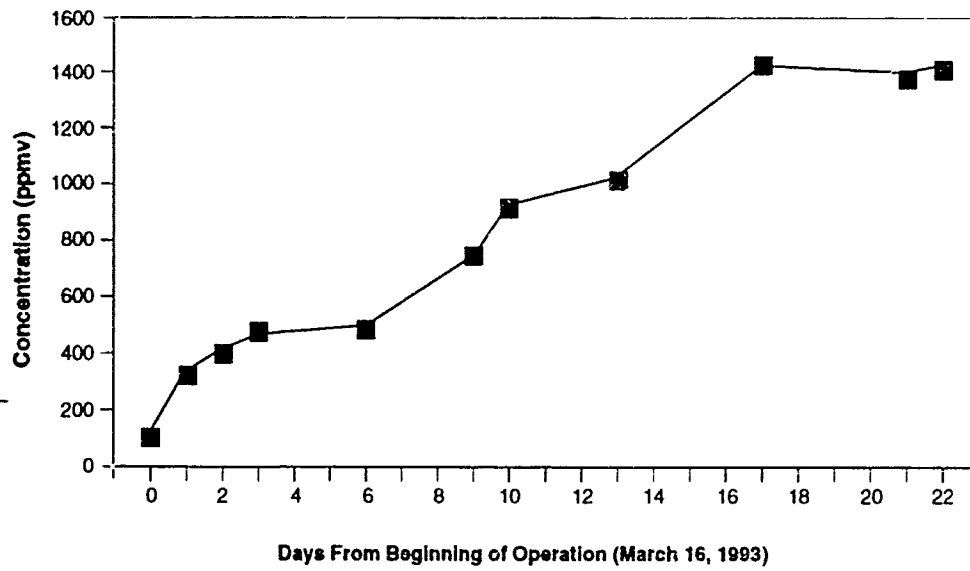
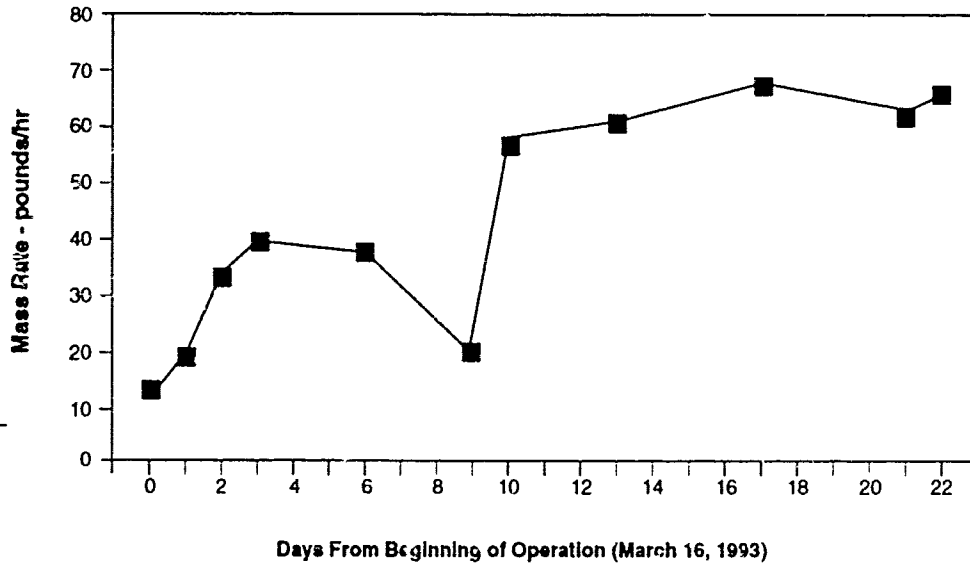


Figure 2-9
SVE Pit Manifold -
VOC Mass Rates



Section 2

Characterization Summary

The biological destruction of about 150,000 pounds of hydrocarbons, and the removal and oxidation of about 46,000 pounds of VOCs exceeds the estimate of 5,800 pounds of contamination inferred from the soil contamination samples. With the caution that the area of withdrawal is not well defined, these results appear to demonstrate substantial uncertainty in using limited soil concentration data to compute contamination mass. The SVE operation demonstrates that substantial quantities of these pollutants are present at Site S, and that the SVE system is effective for their removal.

Section 3

JUSTIFICATION OF SVE REMOVAL ACTION

Sufficient data are not available to perform detailed source modeling for Site S. However, the actual SVE data demonstrate clearly that there are large quantities of pollutants within the withdrawal range of the existing SVE system. These pollutants include both chlorinated hydrocarbons and petroleum hydrocarbons. The SVE system is effective in removing these pollutants directly and by the biodegradation resulting from the aerobic conditions that SVE produces.

It is known that there is a soil gas plume migrating off base from the OU D area, of which Site S is a part. In addition, there is groundwater contamination in the vicinity of Site S. It is highly likely that the pollutants from Site S contribute to these problems.

Therefore, a conversion of the Site S Treatability Investigation to an EE/CA removal action is appropriate to prevent off-site migration and additional groundwater contamination.

Section 4

REMOVAL ACTION OBJECTIVES

Scope

The major objective is to continue the removal of contaminants at Site S, both by establishing aerobic conditions in the area, and by direct removal and destruction of contaminants. This will require additional wells to assist in removal and to more clearly identify the area of contamination. The process for achieving this objective is described in the next section.

A secondary objective is to conduct the data collection and analysis that will increase knowledge useful in applying SVE to McAFB, and to accomplish the remaining goals of the Treatability Investigation. The current SVE Treatability Investigation is designed not only to verify the applicability of SVE technology, but to develop additional information on the operation of SVE. Table 4-1 shows the objectives of the current SVE Treatability Investigation.

While the data taken thus far support several of the Treatability Investigation objectives, they are not sufficient to accomplish all the objectives. However, achievement of these objectives would not only assist in the continued cleanup of Site S, but would assist in the design and operation of the SVE system as expanded to the remainder of the OU D and McAFB. This also will support the Record of Decision as it is ultimately developed for this area of OU D.

SVE Objective	Status
Quantify mass of contaminants removed	Under way
Evaluate reduction of specific contaminants	Under way
Evaluate benefits of hot-air injection	Planned
Evaluate vadose zone transport processes	Planned
Evaluate degree of biodegradation	Planned
Identify strata difficult to remediate	Planned
Evaluate performance of SVE emission control	Under way
Evaluate applicability of SVE to OU D	Complete
Assess applicability of SVE at McAFB	Under way

Table 4-1
*Treatability
Investigation
Objectives*

Section 4

The Treatability Investigation objectives will be continued in the Site S removal action conducted pursuant to this document. Increased emphasis will be placed on making the data taken in support of these objectives available to potential users as quickly as possible during the project so that the efficiency of removal can be optimized.

ARARs

Chemical-specific ARARs As identified in the General Evaluation Document
Action-specific ARARs As identified in the General Evaluation Document
Location-specific ARARs None

Section 5

CONCEPTUAL DESIGN AND COST

Well Installation

The initial operation of the SVE system for Site S has verified the basic design and effectiveness of the system. The only apparent problem area has been emission of nuisance levels of acid gas from the destruction of the VOCs. This will be corrected with the addition and demonstrated operation of the acid gas control system. A lesser problem has been excessive noise from the SVE system. Noise abatement modifications will address this issue.

As discussed in section 2, the confinement of the air flow by the impermeable cap appears to extend the air path to the edge of the cap. With the absence of monitoring wells around Site S, there is no way to determine the location or extent of the area from which the pollutants are withdrawn or biodegraded. In theory, the Site S system operated alone could remove pollutants from beneath the entire cap; however, since the quality of the cap and the air flow paths are unknown, it is unlikely that a removal to a particular standard could be obtained by a single set of extraction wells in the confined location of Site S.

Additional wells will be necessary in the area around Site S. They will serve three purposes.

- To identify the location of the contaminated area being remediated by the SVE system
- To identify the locations of additional areas of contaminants
- To improve the efficiency of the contaminant withdrawal

SVE System Expansion and Operation

While the present SVE system is effective in withdrawing and treating contaminants, additional extraction wells will allow continued high cleanup rates as the areas nearest the present wells are remediated and concentrations in those wells decline. VOC gas concentrations of more than 1,000 ppmv indicate the possible presence of free product under the cap at OU D. A major benefit of expanding the SVE system is to ensure that any areas of free product will be located and remediated.

The expansion of the removal operations at Site S will be conducted using a phased approach, as indicated in figure 5-1. The initial step is to install wells at about 150 feet from the present system wherever the circle contacts a known or suspected contamination site, such as a disposal trench. Although the original permeability testing at Site S indicated a radius of influence of 30-60 feet, a larger spacing of wells appears reasonable for the following reasons:

Section 5

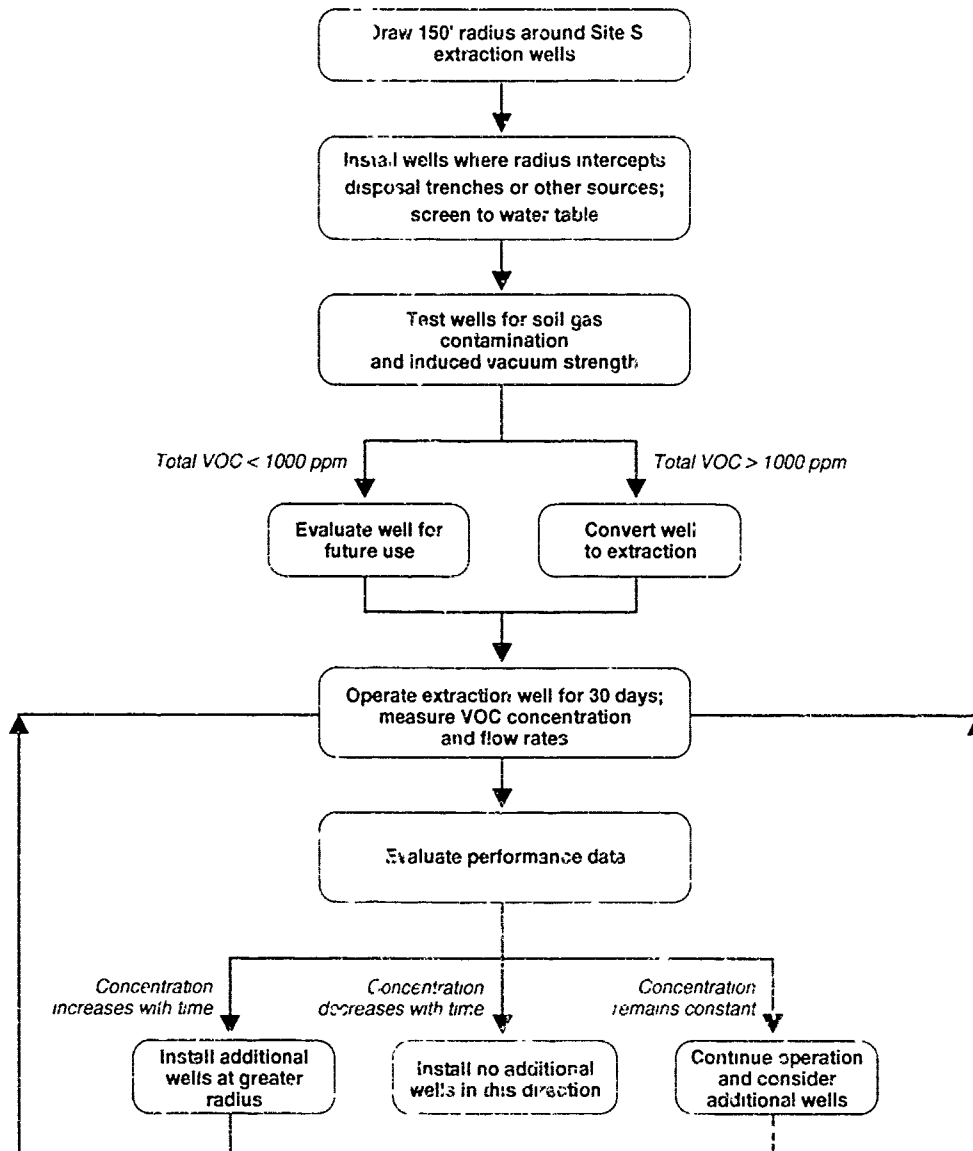


Figure 5-1
SVE System
Expansion
Process

Section 5

- The cap confines underground air flow and increases the effectiveness of withdrawal
- Site S has already demonstrated successful operation
- 150 feet is only 30 percent larger than twice the larger radius of influence

If the concentration is greater than 1,000 ppmv, the well will be converted to an extraction well and connected to the present SVE system. Otherwise, decisions regarding well conversion and operation will be made after consideration of various factors.

Cost Estimate

For the purpose of cost estimating, it is assumed that 20 wells (in addition to the initial Site S wells) ultimately will be necessary at Site S and in the remainder of OU D. These wells may be located over the entire capped area of OU D and will require long runs of piping from the extraction wells to the emission control system. The vacuum pumps and emission control system from the Site S Treatability Investigation can be used to remediate the entire OU D area, so equipment and site preparation costs for these systems are not included in the estimate provided in table 5-1.

The present system has about 50 percent excess blower capacity. To reduce the overall removal time, it may be desirable to use this capacity to serve additional wells while continuing to pump the current extraction wells. It may be necessary to modify or expand the capacity of the SVE treatment system and acid gas scrubber. Costs for these modifications are not included in the estimates.

The period of SVE system operation depends on the amount of free product present at OU D. Based on results of the Treatability Investigation, the removal action could be expected to extend over a two-year period. During this period, any pools of free product will probably be depleted. When containment concentration decreases to acceptable levels near such depleted sources, the affected wells can be removed from the SVE system. At present, quantitative cleanup levels have not been established, but they will be developed through periodic reviews of the SVE system performance. Additional contaminated extraction wells will be added to the system to ensure that containment destruction capacity in the emission control equipment is used efficiently.

Section 5

Cost Item	Design Basis	Unit Cost	Equip. Cost
Site Preparation: Well Installation	20 wells at a total depth of 2,000 feet	\$75.00/foot of depth	\$150,000
Equipment: Manifold and Piping	9,500 feet of 4 to 8 inch PVC pipe, fittings and support	\$30.00/foot	\$285,000
Engineering:	20% of site and equipment		\$87,000
Total: \$522,000			
Operation and Maintenance:	90% uptime, 648 hours per month:		Monthly Operating Cost:
Natural Gas	2425 scfh	\$3.50/1,000 scf	\$5,500
Electricity	105 kw	\$.075/kWh	5,100
Water	617 gph	\$1.00/1,000 gal	400
Scrubber Chemicals	254 pph	\$350/ton	28,800
Waste Disposal	500 gph	\$3.00/1,000 gal	1,000
Testing and Monitoring	1 stack test per month, 9 well analysis per month	\$2,500/sample	25,000
Operating Labor	90 hours for 2 part-time techs and part-time sample collector	\$70/hour	6,300
Reporting	1 monthly operations report and prorated project summary	\$6,000/month	6,000
Monthly Total:			\$78,100

Table 5-1
Site S SVE
System
Expansion
Cost Estimates

Section 6

IMPLEMENTATION PLAN FOR SVE REMOVAL ACTION

The final draft EE/CA document will be available for public comment on 1 September 1993 as shown in figure 6-1. This is followed by a 30-day public review period and a 15-day extension period, for a total of 45 days. A 30-day period follows for McAFB to respond to public comments and to finish preparation of the action memorandum.

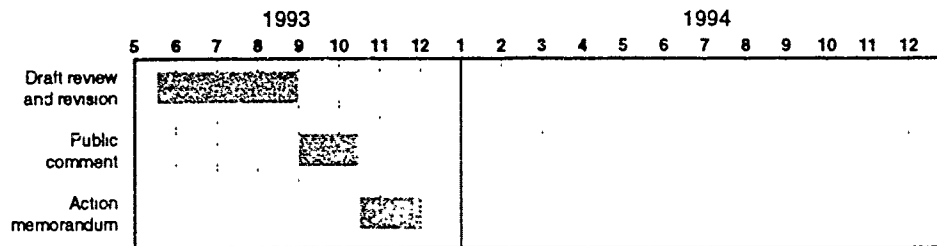


Table 6-1
Schedule for EE/CA
Site Specific
Document for Site S

REFERENCES

CH2M Hill, *Sampling and Analysis Plan, Soil Vapor Extraction Treatability Investigation for Site S Within Operable Unit D*, July 1991

CH2M Hill, *Soil Characterization Technical Memorandum, Soil Vapor Extraction Treatability Investigation for Site S Within Operable Unit D*, April 1992a

CH2M Hill, *100 Percent Design Submittal, Soil Vapor Extraction Treatability Investigation for Site S Within Operable Unit D*, August 1992b.

CH2M Hill, *95 Percent Design Submittal, Soil Vapor Extraction Treatability Investigation for Site S Within Operable Unit D*, August 1992c.

GLOSSARY

Chemical Codes

ACE	acetone
BRME	bromomethane
BUTADIEN	1,3-butadiene, erythrene
BZ	benzene
BZLCL	benzyl chloride
BZME	toluene
C8N	n-octane
CHLOROPR	2-chloro-1,3-butadiene
CLBZ	chlorobenzene
CLEA	chloroethane
CLME	chloromethane
CTCL	carbon tetrachloride
CO	carbon monoxide
CYHEXANE	cyclohexane
DCA11	1,1-dichloroethane
DCA12	1,2-dichloroethane
DCBZ12	1,2-dichlorobenzene
DCBZ13	1,3-dichlorobenzene
DCBZ14	1,4-dichlorobenzene
DCE11	1,1-dichloroethene
DCE12C	cis-1,2-dichloroethene
DCE12T	trans-1,2-dichloroethene
DCP13C	cis-1,3-dichloropropene
DCP13T	trans-1,3-dichloropropene
DCPA12	1,2-dichloropropane
EBZ	ethylbenzene
EDB	1,2-dibromoethane (ethylene dibromide)
FC11	trichlorofluoromethane
FC113	1,1,2-trichloro-1,2,2-trifluoroethane
FC12	dichlorodifluoromethane
FC114	freon 114, dichlorotetrafluoroethane
MTLNCL	methylene chloride
MVC	vinyl chloride, monovinylchloride
NOx	nitrogen oxide
PCA	1,1,2,2-tetrachloroethane
PCE	tetrachloroethene
PROP	propylene, propene
SOx	sulphur oxides
STY	styrene
TBME	bromoform
TCA	trichloroethane
TCA111	1,1,1-trichloroethane
TCA112	1,1,2-trichloroethane

GLOSSARY

TCB124	1,2,4-trichlorobenzene
TCE	trichloroethene
TCLME	chloroform
TMB124	1,2,4-trimethylbenzene
TMB135	1,3,5-trimethylbenzene (mesitylene)
UNK	unknown compounds
VC	vinyl chloride
XYLMP	m,p-xylene (sum of isomers)
XYLO	o-xylene (1,2-dimethylbenzene)
XYLP	p-xylene (1,4-dimethylbenzene)

General

ARAR	Applicable or relevant and appropriate requirements
cfm	Cubic feet per minute
EE/CA	Engineering Evaluation-Cost Analysis
EPA	U.S. Environmental Protection Agency
IAG	Interagency Agreement
IC	Investigative cluster
IRP	Installation Restoration Program
McAFB	McClellan Air Force Base
NCP	National Contingency Plan
OU	Operable Unit
ppb	parts per billion
ppm	parts per million
ppmv	parts per million by volume
scfm	standard cubic feet per minute
SMAQMD	Sacramento Metropolitan Air Quality Management District
SVE	Soil vapor extraction
TRC	Technical Review Committee
VOC	Volatile organic compound